

## Diode Laser Pumped Far-Infrared Local Oscillator Based on Semiconductor Quantum Wells

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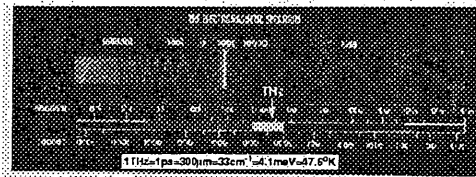
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## Terahertz Field: A Technology Gap

### Need for compact THz sources



- Frequency too high for electronics and too low for photonics
- No mature solid state technology for generation and detection

## Existing THz Sources and Shortcomings

- Molecular lasers pumped by another laser (e.g., methanol laser pumped by CO<sub>2</sub> laser used in the EOS satellite)
- Free-Electron lasers
- P-Ge lasers under B field
- Parametric generators, photomixers in non-semiconductors
- Ultrafast laser generation of oscillating charge carriers

### Shortcomings:

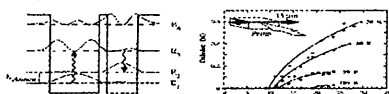
Low output power, low efficiency, low temperature pulse operation, bulky size (need big pump lasers), broadband (not lasers)

## Applications of A THz Laser

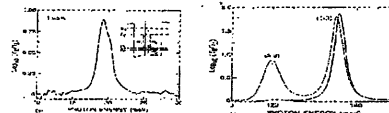
- Terahertz modulation and switching
- Chemical, biochemical, and astrobiological detection and sensing
- Materials and security inspection
- High bandwidth, secure data link
- ..., many more applications

## Previous Optical Pumped LW Generations

- CO<sub>2</sub> laser pumped GaAs/AlGaAs QWs emitting 15.5mm (Paris-Sud) (APL, 71,3619(1997))



- FIR Generation by Double-Resonant DFG (Lucent, APL)



## Optically Pumped Sb-based Intersubband Generation----- Whys

### Why Intersubband?

- Long wavelength generation
- Reduced Auger processes
- Large transition matrix elements

### Why Sb-QWs? (unique bandedge lineups)

- Flexibility in wavelength design
- Deep conduction band wells allowing NIR (diode) laser pumping

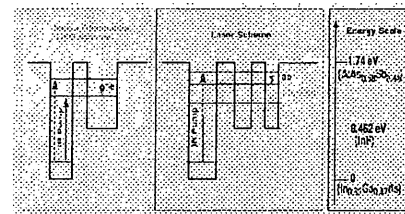
## Optically Pumped Sb-based Intersubband Generation----- Whys

### ⌘ Why optical pumping?

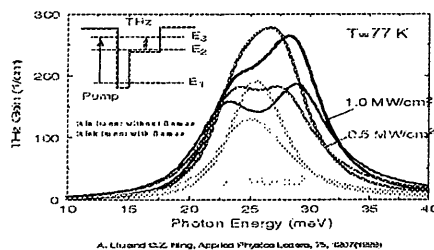
- Less reliant on population inversion
- Utilization of resonant nonlinearities
- Lower carrier concentration and lower free carrier absorption
- Absence of heavily doped layers for contacts and injectors
- Potential integration if diode lasers used as pumping

## InGaAs/InP/AlAsSb QWs

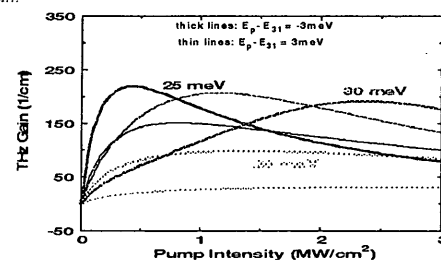
(Lattice-Matched to InP, 5.9Å)



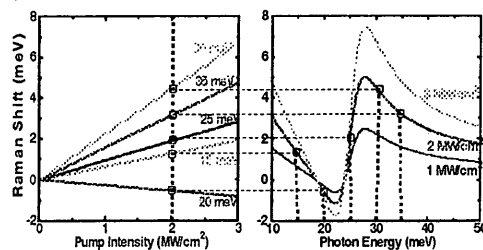
## Raman Enhanced Optical Gain



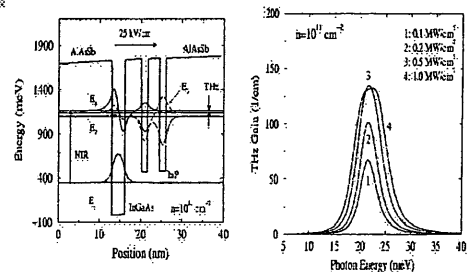
## Pump Intensity Dependence of THz Gain



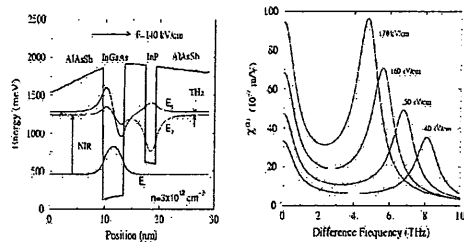
## Pump-Probe Interaction Induced Raman Shift



## THz Laser Gain in InGaAs/InP/AlAsSb QWs

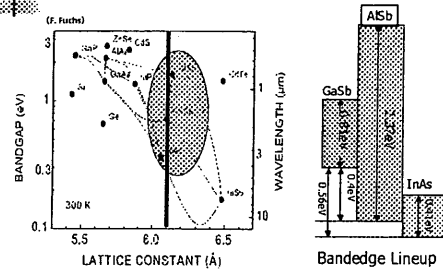


### Diode-Laser Pumped Difference Frequency Generation (InGaAs/InP/AlAsSb QWs)



Liu and Ning, in *Nonlinear Optics: Materials, Fundamentals, and Applications*, OSA Digest, 2000

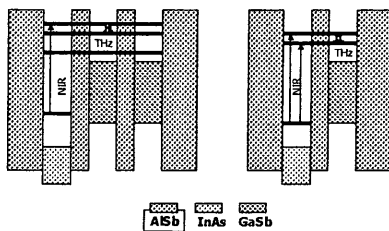
### 6.1 Semiconductor Quantum Wells



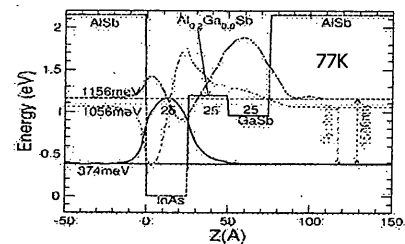
### InAs/GaSb/AlSb Nanostructures

4-Level Laser Scheme

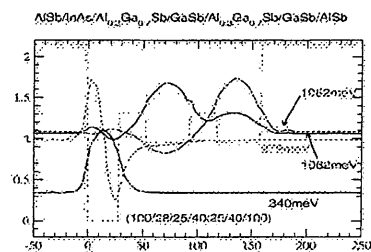
3-Level DFG Scheme



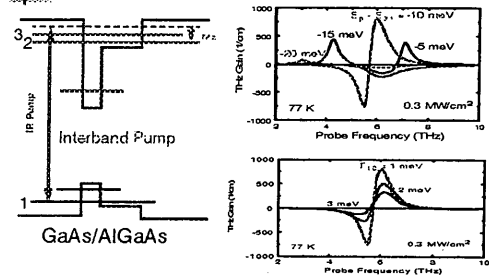
### InAs/AlSb Double QWs: DFG Scheme



### Sb-Based Triple QWs: Laser Scheme



### Exciton State Pumped THz Generation



Liu and Ning, 1999, unpublished